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Fundamental Physics Group

Academic Satff

Professors	Takeshi Ebata, Takashi Kamimura, Haruhisa Miyase, Hiroaki Tsubota, Wakio Uchida, and Hiroshi Yasuhara
Associate Professors	Kazushige Maeda, Masaki Sato, Shozo Suto and Satoshi Watamura
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Research Activities

(I) Elementary Particle Physics

a. Probing symmetry breaking pattern using sfermion masses
(M. Yamaguchi)
We study the mass spectrum of superparticles within supersymmetric grand unified models. For gaugino masses, it is pointed out that the GUT-relation in the $SU(5)$ model is applicable to a more general case where a grand-unified gauge group breaks down to the standard model gauge group by several steps. We also show that the mass spectrum of squarks and sleptons carries the information on the breaking pattern of the gauge symmetry. It is demonstrated in some $SO(10)$ models how the scalar mass spectrum distinguishes various $SO(10)$ breaking patterns from each other.

b. Precision study of supersymmetry at future linear e^+e^- colliders
(M. Yamaguchi)
We discuss a possible strategy for supersymmetry searches and studies at future linear e^+e^- colliders. We demonstrate their effectiveness by Monte Carlo analyses with full angular correlations under realistic experimental conditions including the initial state radiation and the breamstrahlung effects. The importance of precision measurements of supersymmetry parameters is emphasized. We demonstrate that the precision on mass measurements can be as good as 1 % for leptonic and 3 % for hadronic final state. A detailed study on the first superparticle alone gives us an upper bound on the next superparticle. We can also test the basic mass relations assumed in grand unified models or supergravity, such as the gaugino mass relations or the universal scalar mass assumption in a variety of ways. The polarized electron beam plays a crucial role in this study.

c. Light scalar top quark in the minimal supersymmetric grand unified theory
(M. Yamaguchi)
We point out a light scalar top quark with mass as small as $m_{\tilde{t}} \sim 20$ GeV is still an allowed possibility within the standard, minimal supersymmetric grand unified theory, if the photino exists at mass slightly below the scalar top mass, so that coannihilation efficiently takes place of $\tilde{\gamma}\tilde{\gamma}$ in the early Universe. We show that this case, receiving

a number of strong phenomenological constraints, leads us to a restricted pattern of the mass spectrum of other supersymmetric particles.

d. Quantum Deformation of BRST Algebra
(S. Watamura)
We investigate the q-deformation of the BRST algebra, the algebra of the ghost, matter and gauge fields on one spacetime point using the result of the bicovariant differential calculus. There are two nilpotent operations in the algebra, the BRST transformation δ_B and the derivative d. We show that one can define the covariant commutation relations among the fields and their derivatives consistently with these two operation as well as the $*$-operation, the antimultiplicative inner involution.

e. Non-commutative Differential Calculus with Quantum Group Symmetry
(S. Watamura)
We describe the non-commutative differential calculus constructed on the quantum group by using the $\widehat{R}$ matrix.

f. Bicovariant Differential Calculus and q-Deformation of Gauge Theory
(S. Watamura)
The q-deformation of the BRST algebra, the algebra of the ghost, matter and gauge field on one spacetime point is constructed using the result of the bicovariant differential calculus. We define the covariant commutation relation among the fields and their derivatives consistently with the two nilpotent operation the spacetime derivative and the BRST operation.

g. Complex Quantum Group, Dual Algebra and Bicovariant Differential Calculus
(S. Watamura)
Some results about complex quantum group, its dual algebra and bicovariant differential calculus are reported. The motivation of our investigation is to understand deeper the structure of the quantum Lorentz group algebra $\mathcal{U}_q(SL(2,C))$. The infinitesimal q-Lorentz transformation is discussed.

(II) Nuclear Physics

a. $(\gamma,\pi^{\pm})$ Reacation
(H.Tsubota)
The spin-isospin mode in nuclei is investigated by measuring the cross sections and angular distributions of photopions from the $(\gamma,\pi^{\pm})$ reaction near the threshold. This experiment has a feature to be able to measure spin-isospin transitions selectively. The wave functions, the elementary process amplitudes and the pion distortion effect in the nucleus are studied.

b. $(e,e'x)$ Coincidence Experiment
(H.Tsubota and H.Miyase)
In order to obtain the informations for isospin splitting and multipolarities of the giant resonances of ^{12}C and ^{92}Mo, and for the properties of highly excited states and electro- disintegration reaction mechanism in ^{6}Li, the coincidence cross sections

and the angular distributions of protons have been measured at the angles out of the scattering plane with the nuclear experinental group of the Laboratory of Nuclear Science by using the electron pulse beam stretcher at Tohoku University. From these experiments E2 contibutions have been clearly at about 40 MeV for ^{12}C and $\leq$ 24MeV for ^{92}Mo. The cross sections corresponding to protons from p- and s-shell have maxima around 22 MeV and 33 MeV respectively, and this nature is roughly same as the theoretically predicted configulation of the giant dipole resonance in ^{6}Li.

c. (e, f) Experiment

(H.Miyase)

The absolute electrofission cross sections of Au and Ta were measured in the range 25-180 MeV by using the electron linear accelerator of Tohoku University with the nuclear experinental group of the Laboratory of Nuclear Science and the collaborator of University of Sao Paulo. The deduced photofission cross section shows a pronounced dip around the photopion threshold. This (γ, f) dip is interpreted as a consequence of a probable photopion absorption in a stopped pion regime.

d. Study of the nuclear sreangeness with photon and meson probe

(K. Maeda, T. Suda)

Quasi-free K^+ photo-production in the ^{12}C(γ, K^+) reaction has been investigated in the photon energy range of 0.7-1.1 GeV. Differential cross sections for the quasi-free K^+ photo-production have been obtained and they are compared with a calculation in which the Fermi motion of the protons in the p- and s-shell was taken into consideration. The effective proton number $Z_{eff} = 4.2 \pm 0.6$ obtained from the experiment is in good agreement with a calculation of a semi-classical attenuation model.

e. Study of photodisintegration process with intermediate-energy photon beams

(K. Maeda, T. Suda)

The photodisintegration process in the γ +^{3} He, γ +^{4} He, γ +^{6} Li reactions have been excusively studied in the δ-resonance region. We pointed out, specific physical process, for example, the isospin mixing in the δ-excitation, the higher mltipole components and so on, can be observed in the exculded final states.

f. Investigation of the Isovector Giant Quadrupole Resonance in ^{13}C,^{nat} Fe(γ, n) Reaction

(K. Maeda, T. Suda)

Differential cross sections in the ^{13}C$(\gamma_{\text{tagged}}, \text{n})$ reaction at $\theta_{lab.}$ = 55°, 90° and 125° were measured from E_{n} = 17 to 72 MeV. The forward-backward asymmetry, which shows a considerable interference between E1 and E2 photons around the Isovector Quadrupole Resonance region, was observed.

g. LARGE π^+/π^- CROSS SECTION RATIOS IN THE $(\pi, \pi' p)$ REACTION ON ^{2}H, ^{3}HE AND ^{4}HE

(K. Maeda)

Surprisingly large cross section ratios R = $\frac{\sigma(\pi^+, \pi^{+\prime} p)}{\sigma(\pi^-, \pi^{-\prime} p)}$ were reported for the exclusive $(\pi^{\pm}, \pi^{\pm\prime} p)$ reaction on ^{4}He. Whereas the inclusive $(\pi^{\pm}, \pi^{\pm\prime})$ cross sections for ^{4}He gave a π^+/π^- ratio of $\cong$ 1 as expected from charge symmetry, the exclusive reaction

ratios R were found to be as large at 50. These large values were observed at the incident energy T_π = 180 MeV in the region of nuclear excitation energy above 30 MeV and at proton knockout angles near the free π–proton scattering angle. This result is in sharp contrast to the expected value of $\cong$ 9 if the $P_{3,3}$ π–nucleon resonance predominates and if the $(\pi^{\pm}, \pi^{\pm\prime} p)$ reaction proceeds exclusively by quasi–elastic π–proton scattering. Very large ratios had also been observed for $^{16}O(\pi, \pi'$,p) at T_π = 240 MeV [4].

h. Core excited states of $^{12}_{\Lambda}C$ hypernuclei formed in the (π^+, K^+) reaction
(K. Maeda)
A spectroscopic study of the $^{12}_{\Lambda}C$ hypernucleus by the (π^+, K^+) reaction has been performed using a new superconducting kaon spectrometer (INS-SKS) at the KEK 12 GeV PS with an energy resolution of 2 MeV(FWHM). In addition to two prominent peaks which correspond to the *s* and *p* orbitals of a Λ hyperon, for the first time two smaller peaks were clearly observed at excitation energies of 2.6 MeV and 6.7 MeV. These two peaks are interpreted as states where the ^{11}C excited core and a Λ hyperon in the *s* orbit are weakly coupled. The excitation energies and the cross sections of these peaks provide information on the Λ hyperon-nucleon interaction, particularly on the spin-spin part.

(III) Theoretical Solid State Physics

a. A Local-Density Band Theory for the Fermi Surface of the Heavy-Electron Compound $CeRu_2Si_2$
(H. Yamagami)
On the basis of the itinerant-electron model for the 4f electrons, the energy band structure and the Fermi surface are calculated for the metamagnetic heavy-electron compound $CeRu_2Si_2$ having the low-temperature electronic specific heat coefficient γ of 350 mJ/K^2 mol. by a self-consistent symmetrized relativistic APW method with the exchange and correlation potential in a local-density approximation. The main Fermi surface consists of a large closed hole sheet and a complicated electron sheet like a jungle gym. The Fermi surface topology is consistent with the experimental result for the high-field magneto-resistance. By comparison with the electronic structure of $LaRu_2Si_2$, effects of the 4f bands on the Bloch states on the Fermi surface in $CeRu_2Si_2$ are investigated in detail. Strong evidences for existence of the electron sheet are found in available experimental de Haas-van Alphen frequencies. The enhancement factor for γ is estimated as 38.

b. Resonant photoemission in CeNi single crystals
(H. Yamagami)
The valence-band photoemission of the (010) surfaces of CeNi single crystals has been observed. The feature occurring in angle-resolved normal-emission spectra do not show an appreciatable amount of dispersion. The energy distribution curves are squeezed and narrower than those suggested by an existing energy-band calculation. Resonant photoemission has been observed both near the 3p core electron excitation

threshold of Ni and the 4d threshold of Ce. An aspect of the super-Coster-Kronig final state with a post-collision interaction is found near the onset of the resonance in the two-hole bound-state satellite. In addition to the two-peak profile in the overall spectral aspect of the 4f spectrum, two additional feature are resolved. The origin of these features is discussed. The ratio of Fano's q parameters between the $3p$–sd resonance in Ni ions and the $4d$–$4f$ resonance in Ce ions agrees with a result of s simple theoretical analysis.

c. Photoemission study of CeNi single crystals

(H. Yamagami)

Resonant photoemission from the (010) surfaces of CeNi single crystals has been observed around the Ni 3p and Ce 4d core electron excitation threshold. In addition to the two–peak profile in the overall aspect of the 4f spectrum, two additional features are resolved.

d. Electronic structure of UC studied by X–ray photoemission and bremsstrahlung isochromat spectroscopy

(H. Yamagami)

X-ray photoemission and bremsstrahlung isochromat spectra are measured for UC. Valence state spectra are compared with the relativistic APW band calculation. Shape analysis of the U 4f core spectrum is made Doniach–Sunhic lineshape with broadening. The discrepancies between valence spectra and the APW calculation, and presence of U 4f satellites show a correlation effect between U 5f electrons.

e. An energy band picture for the Fermi surfaces of f–electron compounds

(H. Yamagami)

It has recently been revealed that an energy band picture for f–electrons works well in explaining the Fermi surfaces of various f–electron compounds as deduced by the de Haas–van Alphen effect. Recent progress in developing the band theory for the Fermi surfaces of itinerant f–electron compounds is reported.

f. Local–density approach to the Fermi surfaces of $CeRu_2Si_2$ and $LaRu_2Si_2$

(H. Yamagami)

In the itinerant 4f electron model, electronic structures are calculated for $CeRu_2Si_2$ and $LaRu_2Si_2$ by the a relativistic APW method. The main Fermi surface is a large hole sheet in $LaRu_2Si_2$ and a hole and an electron sheet in $CeRu_2Si_2$. Evidence for these sheets is available from published results of de Haas–van Alphen experiments.

g. Effect of non-muffin-tin corrections on the Fermi surface of CeNi

(H. Yamagami)

In the itinerant 4f electron model, the effect of non-muffin-tin corrections on the Fermi surface of CeNi is investigated by an FLAPW method. It is found that the non-muffin-tin corrections are small and the basic topologies of the main hole and electron sheets do not change.

h. Fermi surface of the ferromagnetic heavy-electron compound UGe_2

(H. Yamagami)

In the itinerant 5f electron model, the Fermi surface is derived phenomenologically for the heavy-electron ferromagnet UGe_2 using a relativistic APW method. The main de Haas-van Alphen frequencies together with the cyclotron effective masses can be explained reasonably well.

i. Survay of the Charge Excitation Gap by a 2D filter
(T. Nishino)
The charge excitation gap of lattice electron models is expressed as a linear combination of ground-state energies for several electron densities. The many-body effects of small Hubbard and periodic Anderson clusters are surveyed for both half-filled and non-half-filled bands.

j. Strongly Correlated Features of an Electron Gas at Metallic Densities
(H. Yasuhara)
Two aspects of the strongly correlated features of an electron liquid at metallic densities are discussed: the short-range correlation between electrons with opposite spins and the very complicatedly renormalized features of many-body effects on the effective mass.

(IV) Surface Physics

a. Adsorption of C_{60} molecules on Si(100)2x1 surface
(S. Suto)
In order to understand the interaction between C_{60} and dangling bonds on Si(100) surface, the inelastic electron-energy-loss spectra has been measured in the infra-red energy range. If C_{60} is evaporated 5 Å(approximately half a monolayer) on Si(100), a strong loss peak appears at 65 meV, and weak peaks and shoulders at 72, 144, and 175 meV. In the 12 Åthick film, additional weak peaks at 96, 160, and 189 meV become more apprent. Intensities of these peaks are comparable to those of thick films measured by infra-red absorption and by Raman scattering spectroscopies. Moreover, we have measured the angle dependence of the inelastic electron intensity. These results suggest appreciable interactions between C_{60} and the dangling bonds of Si surface.

b. Improvement of Physics Education (W. Uchida)
(1) We have studied the present situation of experimental physics courses at 118 universities in Japan, and analyzed problems with the financial support by the Ministry of Education, Science and Culture. We have proposed the ideal curriculum in the near future.
(2) The new curriculum in physics has been taken for undergraduate course students in Tohoku university since April, 1993. The present status in basic physics courses are analyzed precisely.

(V) Magnetism

a. Magnetic properties of (Fe,Co)-Se system
(T. Kamimura and M. Sato)

High pressure X-ray and zero-field NMR measurements were made on $(Fe_{1-x}Co_x)_7Se_8$. A pressure-induced phase transition takes place up to the magnetic critical concentration $x \sim 0.6$ at room temperature. The Co atom as well as the Fe atom possesses a magnetic moment for $x < 0.6$. These results are discussed in view of a close correlation between the magnetism and the lattice spacing c in these compounds.

b. Magnetic properties of the hexagonal $BaFeO_{3-y}$
(H. Kobayashi)
We have measured the ^{57}Fe Mössbauer effect in hexagonal $BaFeO_{3-y}$ system with different oxygen contents. The Fe sites are subdivided into two electronically nonequivalent sites, that is, one is a tetravalent site and the other a trivalent one. The Fe^{4+} concentration decreases not only with increase of oxygen vacancies but also with temperature. In $BaFeO_{2.88}$, the magnetic order occurs at 130 K and the temperature dependence of Fe^{4+} concentration changes around 170 K.

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